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Introduction

In the realm of cognitive health research, understanding the progression and impact of dementia is a pivotal aspect. Our investigation centers around the analysis of cognitive function through MMSE scores, a widely recognized tool for assessing cognitive impairment. The MMSE provides insights into various cognitive domains, including memory, attention, language, and spatial skills. Our study intends to shed light on the cognitive decline patterns associated with dementia, offering a valuable perspective on the disease's progression over time.

Central to our exploration are two research questions that guide our study:

1. How do MMSE scores, as indicators of cognitive function, differ between dementia and non-dementia patients across successive visits?
2. Does the number of visits (time) influence the trajectory of MMSE scores in dementia patients compared to their non-dementia counterparts?

Exploratory Data Analysis

In this analysis, we examine MMSE scores to assess cognitive function among patients with varying dementia statuses over multiple visits. The MMSE score histogram(Fig.1) reveals a skew towards higher scores, indicating generally good cognitive function among our subjects.

The boxplot (Fig.2) delineates clear distinctions in MMSE scores among non-demented, demented, and converted groups. Nondemented subjects have higher scores on average, whereas demented and converted subjects display lower cognitive function.

A line plot of MMSE scores(Fig.3) over time shows a declining trend for all groups, with demented and converted individuals experiencing a more pronounced decline. This observation is in line with the expected progression of dementia.

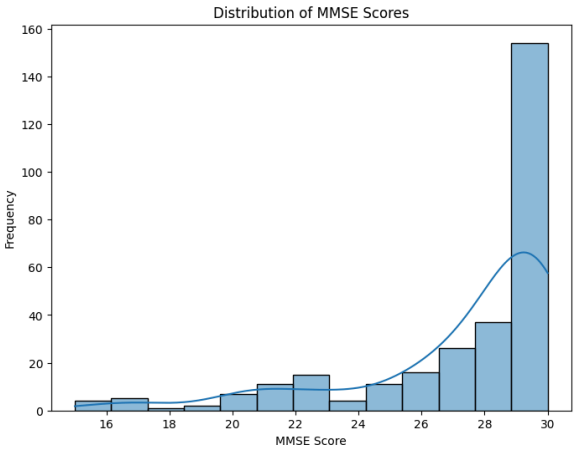

Fig.1 Distribution of MMSE Scores

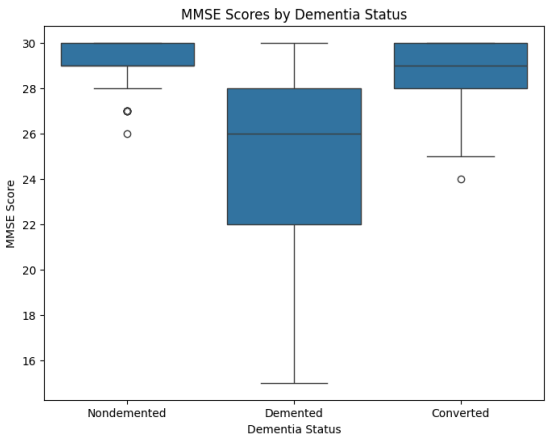

Fig.2 MMSE Scores by Dementia Status

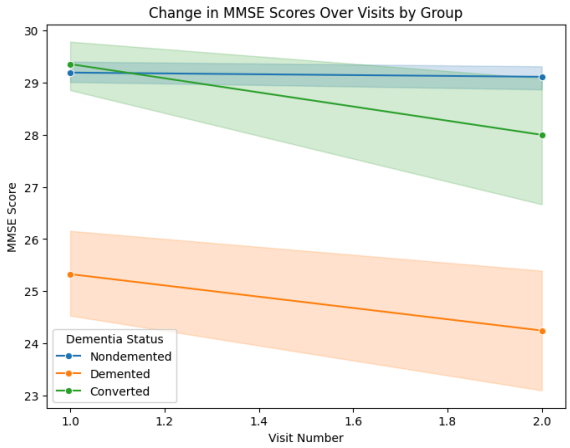

Fig.3 Change in MMSE Scores Over Visits by Group

Quantitative Analysis

After a preliminary visual analysis, we used a mixed-effects ANOVA to compare cognitive functioning across different dementia statuses and visits.

Source	SS	DF1	DF2	MS	F	p-unc	np2	eps
Group	1328.421218	2	140	664.210609	56.212233	< .00001	0.445379	NaN
Visit	22.377622	1	140	22.377622	8.859368	.00343	0.059515	1.0
Interaction	17.000403	2	140	8.500201	3.365255	.0377081	0.045870	NaN

Table 1. ANOVA Results

From these results, we see significant main effects for both the 'Group' ($p < .0001$) and 'Visit' ($p = .00343$), suggesting that both the dementia status and the visit number have significant impacts on MMSE scores. Additionally, there is a significant interaction effect ($p = .0377081$), which implies that the rate of change in MMSE scores varies between dementia and nondementia groups across different visits.

The size of the effects is also of interest; the group factor has a large effect size ($np2 = 0.445379$), indicating a strong association between dementia status and MMSE scores. The visit number, while statistically significant, shows a smaller effect size ($np2 = 0.059515$), pointing to a more modest influence on the scores over time.

These findings indicate that the decline in cognitive function, as visits progress, is not uniform across all groups; patients with dementia or those who have converted show a different trajectory compared to those without dementia. This sets the groundwork for further post-hoc analysis to explore these differences in detail.

Test Assumptions

From the Shapiro-Wilk test, we observe that the normality assumption is not met for any of the groups ($p < 0.05$), indicating that the MMSE score distributions are not normal. Additionally, Levene's test indicates that the assumption of equal variances is also violated. Given the non-normal distribution of our data, the violation of equal variances suggests that our ANOVA model must account for heteroscedasticity, or we may need to explore other statistical methods robust to these assumptions.

Group	W	pval	Normal
Nondemented	0.809528	2.635762e-12	False
Demented	0.929083	5.677786e-06	False
Converted	0.770938	5.867723e-05	False
levene	NaN	NaN	False

Table 2. Shapiro-Wilk Test for Normality

Post-Hoc Tests

Following the ANOVA, post-hoc tests were conducted to further investigate the differences between groups and visits. Significant differences were found when comparing the converted group with the demented group at visit 1 ($T(60.516) = 8.01$, $p < .00001$) and when comparing the same groups at visit 2 ($T(33.887) = 4.55$, $p < .0001$). The comparison between the demented and non-demented groups at visit 2 was highly significant as well ($T(64.937) = -8.46$, $p < .00001$), indicating that visit number has a different impact on MMSE scores for patients with dementia compared to those without.

	Contrast	Visit	A	B	Paired
0	Visit	-	1	2	True
1	Group	-	Converted	Demented	False
2	Group	-	Converted	Non-demented	False
3	Group	-	Demented	Non-demented	False
4	Visit * Group	1	Converted	Demented	False
5	Visit * Group	1	Converted	Non-demented	False
6	Visit * Group	1	Demented	Non-demented	False
7	Visit * Group	2	Converted	Demented	False
8	Visit * Group	2	Converted	Non-demented	False
9	Visit * Group	2	Demented	Non-demented	False

	Parametric	T	dof	alt	p-unc	BF10	Hedges
0	True	2.928	142.000	two-sided	3.973e-03	5.53	0.162
1	True	6.739	51.064	two-sided	1.399e-08	2.036e+06	1.167

2	True	-1.303	12.315	two-sided	2.165e-01	0.599	-0.584
3	True	-9.449	64.318	two-sided	8.946e-14	2.207e+13	-1.754
4	True	8.012	60.516	two-sided	4.424e-11	3.187e+08	1.314
5	True	0.489	13.999	two-sided	6.327e-01	0.336	0.167
6	True	-9.016	66.849	two-sided	3.652e-13	2.117e+12	-1.668
7	True	4.548	33.888	two-sided	6.618e-05	759.706	0.899
8	True	-1.816	11.802	two-sided	9.491e-02	1.126	-0.937
9	True	-8.463	64.937	two-sided	4.430e-12	1.106e+11	-1.570

Table 2. Post-Hoc Test

Power Analysis

We aim for a power (1-β) of at least 0.8, which suggests an 80% chance of detecting an effect. The analysis revealed that a sample size of approximately 45 individuals per group would provide sufficient power to detect differences in MMSE scores between groups across visits. This information is pivotal when considering the scale and scope of future studies, ensuring that we gather enough data to draw meaningful conclusions without unnecessary resource expenditure.

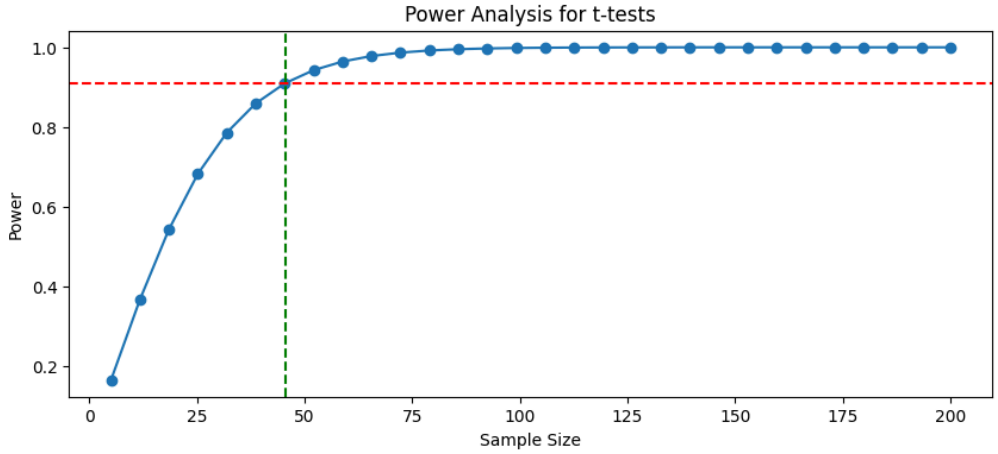

Fig4. Power Analysis

Conclusion

In conclusion, our exploratory and quantitative analysis revealed significant differences in cognitive function, as measured by MMSE scores, between individuals with and without dementia over time. Dementia status had a pronounced impact on cognitive scores, with time also playing a significant role. The interaction between these factors was notably significant, highlighting the varying trajectories of cognitive decline across different groups. These insights contribute to the understanding of dementia's progression and emphasize the importance of timely interventions. The power analysis suggests a sample size of around 45 per group would be suitable for detecting differences in subsequent research, enabling effective use of research resources.